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DRAWINGS ATTACHED.

1,117,401

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COMPLETE SPECIFICATION.

A Connector Assembly for an Electrical Welding Installation.

I, WILLIAM ARMAND TOTO, a Citizen of the United States of America, of 3645, Warrensville Center Road Cleveland 22, Ohio, United States of America, do hereby declare the invention, for which I pray that a patent may be granted to me, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to a connector assembly for an electrical welding installation and more particularly to an alternate polarity multiple conductor connector assembly having a greatly extended operating life due to an improved end structure which reduces fatigue chafing of the fine wires induced by twisting of the wire and which greatly facilitates the problem of dissipating large quantities of internally generated heat.

According to the present invention there is provided a connector assembly for an electrical welding installation comprising a kickless electric cable having helically disposed ropes of conductor strands, and including means for supporting the ropes, said means being located internally of the conductor ropes of the cable and in a region towards an end of the cable and presenting helical grooves each supporting a rope, the helical angle of the grooves being approximately equal to the helical angle of the lay of the ropes, said grooves providing sliding surfaces for the supported ropes, whereby to hold the ropes apart and facilitate their relative longitudinal movement without chafing during bending and twisting of the cable in use, conductive connector means being provided for securing the assembly to said installation. These surfaces permit free movement of the ropes and prevent chafing of the fine wires while maintaining the ropes in spaced apart relationship thus maintaining open the coolant flow passageways when the cable is bent at the welding gun end. A spiralling shaped swaged connector may be provided for connecting the ropes of one polarity to the welding gun. The connector's shape approximates the helix of the rope lay, mating in overlapping relation with an opposite polarity connector containing an aperture for passage of coolant flow.

At each end the cable preferably consists of two leads wound about a perforated resilient sleeve containing a collapsible hollow core element such as a helical spring. The end of the core element has a helically shaped semi-rigid spacer located six to eight inches beyond the terminal at the transformer end of the cable, enabling the coolant to be conveyed directly to this region, thereby forming a coolant pocket between the spacer and the end of the connector. This arrangement ensures that coolant is always accessible to the rope conductors at the hottest portion of the cable. Coolant flow is distributed over the outer rope conductors of the cable by means of an outer or major connector surface formed with a circumferential manifold groove connecting with two helical flow channels.

In my co-pending Patent Application No. 30682/66 (Serial No. 1,117,402) there is described and claimed an electric cable having an improved wear-point reducing strand configuration for the negative wire ropes. Said cable comprises a 14 bunch rope construction of fine stranded wire composed of a core of 4 bunches surrounded by a peripheral layer of 10 bunches. The twist direction of each bunch is opposite to its adjacent bunch in the outer and inner core groups. Each bunch in the core group has a non-circular transverse cross section to establish points of physical contact with

bunches of the outer group. The closing helix of both the outer and core groupings is the same and has the same direction to maintain, the direction of the helix angle of the formed negative connector. Thus, wear caused by induced magnetic fields, as well as by physical contact of the bunches, in each rope is reduced.

For an introductory discussion of prior art arrangements relating to welding cable assemblies, reference to applicant's U.S. Patent No. 3,127,467 may be made.

The kickless cable referred to has alternating polarity configuration wherein multiple strand cable lead conductors are alternately spaced on a circle about the longitudinal axis and spirally wound about a core, and incorporating inner and outer non-conductive sheaths adapted to internally separate the conductors of opposite polarity, both leads of which are jacketed by a flexible hose capable of carrying coolant water.

Perhaps the most important practical consideration for efficient cable usage is the problem of removing the heat generated by the cable's resistance. The basic heat equation

$$W = I^2RD$$

where W = Watts—heat
I = Current—amps
R = Total resistance
D = Duty cycle or on time

very nearly illustrates the large quantities of energy dissipated in ohmic heating and which must be removed by the coolant flow in order to achieve the maximum potential of the cable's MCM size and to prevent the premature deterioration of the cable.

It should be noted here than the I^2 term commonly varies between 10^8 to 4×10^8 and that the resistance value (R) increases 3.5% with each 10°F. rise in temperature of the copper. This increase in copper's resistance, of course, aggravates the problem by completing the viciously ascending heat generating cycle.

This problem is further complicated when the welding gun operator severely bends or twists the welding gun and cable assembly in order to perform his spot welding operations on a moving auto body. These bends will restrict the flow at the kinked cable areas, thereby causing localized heat spots. An alternately wound "kickless" cable is divided into two concentric groups of ropes by a thin rubber tube. The tube serves as a separator and insulator for the two cable leads. It has been an undesirable characteristic of this cable to exhibit a major unbalance division of flow between the central flow through the inside of the separator when compared to the external flow outside of the separator. The conductors inside the separator will always receive less than half of the flow. This imbalance is caused by the twisting and tightening action of the helix on the cable assembly. The inner group of conductors are forced to hug the solid core. Similarly, the separator becomes tightly wound about the inner group of conductors, with the net result of closing up the inner or positive flow passageways, while increasing the size of the outer or negative flow passageways. When the assembled cable is subjected to line pressure, the cable's outer hose or jacket will expand and further open up the outer negative flow passageways about the outer group of cables, thereby causing an even greater unbalance flow condition.

This condition, as well as the others previously described, will produce localized cable hot spots along the inner group of rope conductors that will seriously damage the separator and cause the two leads to short out causing the cable to quickly destroy itself.

It now becomes apparent that the major cause of cable failures are either of two types: (1) Separator failure or "burn-out" caused by hot-spot 6 to 8 inches beyond the terminal at the transformer end of the cable; (2) mechanical breakage of the fine wires 6 to 8 inches beyond the terminal at the gun welder end of the cable.

Separator failures are common when the surface temperatures of the strands exceed 250°F. during continuous operations. The separators generally extruded from the Buna-N compounds can be expected to rapidly deteriorate and flake away. Their residues can be found as deposits on the coolant stream passageways of the cable and its terminals, and they will further impede the flow and accelerate cable failures. The cable area 6 to 8 inches beyond the terminal lugs at the transformer connection is most detrimentally affected by the high temperatures of the coolant flow, since at this point a balance is reached between the heat dissipated into the transformer lugs and the high point of the longitudinal temperature gradient along the cable's length. It is at this point that many cables fail because of the insufficient heat transfer rate due to the large amount of accumulated heat in the coolant flow stream by the time it reaches its area coming up from the gun end of the cable.

The other equally serious problem causing failures in cables is brought about by mechanical fracturing of wires also in the area 6 to 8 inches beyond the terminal at the gun end previously described in applicant's U.S. Patent No. 3,127,467. This type of breakdown is caused by the mechanical bending stresses imparted to the wires as

the cable is kinked or bent by the operator. When the cable is sharply bent the three inner conductors are unable to realign themselves into compensating positions because of high frictional forces, and thereby restrict the water flow at this area which further accelerates the breakage to the fine wires.

It is the object of the present invention to provide internal and circumferential bearing surfaces for each of the six rope conductors at the area to the rear of the terminals at the gun end of the cable in order to overcome wire fracturing at this point, when the cable is severely kinked.

Another object of this invention is to provide a terminal connector to position the inner and outer conductors so that they are free to align themselves behind the terminals during severe bending of the cable.

Other objects of the invention will in part be obvious for a fuller understanding of the nature and objects of the invention. Reference is made to the following detailed description taken together with the accompanying drawings in which:

Figure 1 is a fragmentary diagrammatic view of a connector assembly of the present invention;

Figure 2 is a fragmentary isometric view of part of a preferred embodiment of the connector assembly of Figure 1 showing the positive connector lead disconnected from the terminal assembly.

Figure 3 is a fragmentary plan view of Figure 2 taken substantially on line 3—3;

Figure 4 is a vertical sectional view taken substantially on line 4—4 of Figure 1;

Figure 5 is a vertical sectional view taken substantially on line 5—5 of Figure 2; and

Figures 6, 7 and 8 are transverse cross-sectional views of the cable assembly of the invention along the cuts 6—6, 7—7 and 8—8 of Figure 3.

Referring to Figures 1, 2 and 3, the flexible water-cooled electric connector assembly of the present invention is generally designated by reference numeral 10. The connector assembly 10 is shown extending between transformer T and welding gun W. Connecting the connector assembly 10 to the transformer and welding gun are shown two terminals each composed of two conductive elements 11 and 12, positive and negative respectively, insulatingly separated by a conductive block 11*a*. Bolts 13 passing through a hole in terminals 14 and insulators 15 secure the elements to the terminals. The conductive elements 11 and 12 may be a flexible lamination of copper strips composed of a pair of identical semi-cylindrical sections, generally machined from round copper stock and sawed into two semi-cylindrical lengths. The shape of the conductive elements 11 and 12 can be made to suit most any application. A relatively thin flat insulating element 16 insulates conductive block 11a from element 12 along their joint faces. Threaded holes 18, shown in the conductive block 11a, are used for fastening the conductive element 11 to the terminal. Coolant ports 19 and 20, located in the block 11a in each terminal assembly, are threaded to receive hose fittings carrying coolant to the cable. The coolant is introduced at the welding gun end, i.e. through part 19 which end is usually the lowest point in the suspended cable so as to flow upward through the cable and emerge from port 20 in the top terminal that is attached to the transformer T.

In the preferred embodiment as shown in Figures 2 and 3, the rearward end of each conductive element 11 and 12 is radially undercut to form axially projected, doubly bevelled tangs 21 and 22 that are integral with the body of the conductive element 12, and are each adapted to receive in mating arrangement forming a strong lap joint a cable lead connector whose outer surface 23 is generally arcuate in form in order to snugly fit within the internal diameter of a cable hose 5. A negative connector 26 and positive connector 24 are bolted to the tangs 21 and 22 using 18-8 stainless steel bolts 25. This lap joint can further be secured by silver soldering the mating surfaces together.

The interior faces of the conductive elements 11 and 12 may be provided with axial grooves or channels 27 (Figures 3 and 7) and the insulating element 16 is slotted in this area to match the channel opening in order to facilitate the coolant flow through the channel. The channel then becomes the common distribution point for the division of flow for the positive and the negative coolant flow passageways.

It will be noted that when the terminal is assembled, inward facing surfaces 28 (Figure 3) of the tangs 21 and 22 are spaced apart to form a coolant portioning port 29 for controlling the negative flow, e.g outer flow, to the negative outer group of 3 ropes. The flow to the negative lead (outer flow) can be varied by tapering the sides of the tangs 21 and 22 in conjunction with varying the crosswise length of the dividing insulating element 16 at point 30. Accordingly, decreasing the taper and increasing the length will tend to decrease the negative flow (outer flow) over the negative conductors and thus it is possible to meter and to balance the negative and positive flows.

As shown in Figure 2, it should be noted that the positive connector 24 has been shown disconnected from the positive terminal tang 21. Two bolts 25 pass through the connector clearance holes 31 and are threaded into holes 31a of the tang 21.

This better illustrates the construction details of each of the connectors. Similarly, negative connector 26 can be disconnected from the tang 22 by removing the threaded bolts 25. The negative connector 26 ties together as a conductive unit. The terminal end portions of each group of 3 negative core conductors 32 of like polarity are inserted into a preformed conductive metal sleeve 33 and swaged together in a heavy press using a progressive type die in order to achieve an intricately contoured shape. This connector 26 transpositions the 3 conductors from their outer circumferential positions into a common semicircular cross section. The connectors in this description are twice the length of those set forth in Applicant's U.S. Patent No. 3,127,467 and each contain two helically fluted grooves on a circumferential surface and are shown as 33a. The fluted recesses 33a act as flow channels to convey coolant flow passing through the tang flow proportioning port 29 and hence around a manifold flow groove 34 which in turn feeds the two fluted grooves 33a. The coolant flow can now flow evenly distributed along the 3 outer negative conductors for efficient removal of heat generated. The helix angle in the connector is approximately 30°. The conductors thus maintain the same helix angle through the connector collar as they have throughout the length of the cable.

The present conductor construction comprises a novel 4 core and 10 peripheral conductor bunches to form a stable configuration in which elliptically-shaped bunches are present in the core to support the outer bunches. This elliptical core configuration, allowing 6 cross-over points, is new in the electric cable field.

In contrast to 35 chafing points for the concentric 7 × 9 rope, the 14 bunch "herringbone" herein reduces wire fracture by providing greater lateral contact surface areas than in the "35 cross-over point" of the prior art cable. As the contact areas become greater, the wearing pressures become smaller.

It has been verified by extensive testing (to be described later) that it is important to the life of the cable, particularly in the area behind the terminal, that the strand approaching angle into the connector collar should be the same as the outer helix angle of the strands. All presently marketed kickless cables make no provision for attaching the rope strands to the terminals so that the helix angle is maintained at the entrance to the rear of the terminals. Unless this is done severe bending stresses are imposed on the strands because they are caused to turn a sharp corner upon entering the terminals.

In the present invention the connector section at the manifold groove line makes a smooth transition from the helix angle to one that is parallel to the longitudinal axis of the cable. Since this transition is carried out at a rigid section of the cable, no bending stresses are imparted to the strands. Further, the connector openings have been designed with a generous tapered and flared entry portion 35 to permit additional freedom of wire movement while the cable is being bent.

As stated at the outset, cable conductors attached to terminals at the welding gun end of the cable have a tendency to fail in the immediate area of the cable to terminal connection. This failure is attributed in large measure to the repeated subjection of the cable conductors to severe bending stresses in this area since the cables are acutely bent by the welding gun operator. In order to overcome this difficulty, support means is located in the vicinity of the end of the cable and externally of the ropes 32 and 38. Said support means is in the form of a 0.060 inch wall semi-rigid nylon sleeve 36 which extends beyond and the two connectors for at least 1½ times the cable's diameter and which is located within the common cable hose 5. The sleeve serves two purposes: (1) It provides a better bearing surface over which the outer 3 strands are able to slide. (The co-efficient of friction of nylon is considerably less than that of rubber). (2) The nylon sleeve offers just the proper amount of semirigidity to the area so as to increase the radius of curvature of the cable while it is being kinked so that the outer strands are not subjected to the high localized bending stresses.

The sleeve 36 also serves the function of covering the grooves 33a of the negative connectors preventing the rubber hose from closing in on them and thereby becoming coolant tunnels for the negative flow.

In Figure 2 an exploded fragmentary view depicts the cable's outer jacket or hose 5 cut away and the positive connector lead 34 disconnected from the tang 21. An inner resilient insulating sheath 37 (Figure 8) is used as the insulator enclosing one set of positive conductors 38, wound about a central core assembly. The negative conductors 32 are helically wound and in alternating positions with the positive strands. Both groups are insulated from each other by the insulating sheath 37. Sheath 37 has been pulled away from the cable and is shown in Figure 2 in a relation which illustrates the structural interrelation of a helically grooved or fluted nylon conductor bearing 39 and the core assembly that is composed of an open pitch brass spring 40 inserted into an oversized perforated resilient tubing 41 which is located centrally of the cable. The inner nylon bearing which

is located internally of the positive conductors 38 of the cable has a central bore and is approximately 0.75 inch long with 6 arms 0.375 inch long and located 0.25 of an inch beyond the end of the circumferential nylon sleeve 36.

The bearing 39 has helical flutes 42 (Figure 4), is shaped to snugly fit the 3 positive conductors 38 and is held in contact with the positive conductors by the spring 40 which passes through its central bore. The bearing is restricted from moving down the length of the cable by the perforated resilient tubing 41, and it cannot move towards the positive connector because the conductors 38 are brought together in tight relation as they enter the connector 24. It can now be appreciated that as the cable is severely bent beyond the terminal, the negative or outer group of 3 conductors will slide along the inner surface of the nylon sleeve 36 and concurrently the inner or positive group of 3 conductors 38 will slide along the helical flutes 42. The combined action of the nylon sleeve 36 and the nylon bearing 39 imparts universal bearing action to each of the 6 ropes of the cable. This results in even sliding action overcoming the concentration of bending stresses on the strands by allowing for their mutual movement and realignment throughout the cable's bending cycle.

The conductor portion immediately forward of the internal nylon bearing 39 of the positive lead is most adversely affected by high temperatures generated by the heavy current flows, and for efficient operation according to the invention, coolant reaches this portion in plentiful quantities about the congested conductors, particularly when the cable is bent. It can be seen in Figure 3 that in the vicinity of the spring 40 and the bearing 39, there is created a space providing reservoir pocket for free-flowing coolant that may intimately flush the major portion of the conductors in the area, thereby providing an ideal turbulent flow condition for good heat transfer action.

The spring 40 is inserted into a flow metering port 43 axially located in the positive connector 24. This port 43 may be drilled after the connector has been formed by swaging. The diameter of the part 43 is variable to balance out the system's distribution of flow.

The spring 40 continues through the bearing 39 and acts as a core, jacketed by a perforated resilient tube whose internal diameter is 35% greater than the spring's outside diameter. The other end of the cable, i.e. the transformer end, is identical to that shown in Figure 3 except the ports in the terminals become outlets instead of inlet ports.

Further reduction in the wear of the cable is provided by the strand grouping, shown in Figures 4, 5 and 6, whereby, as designated in Figure 4, each rope consists of 14 strand groups arranged in an outer or peripheral group 51 of 10 strand groups 51a, 51b, 51c, 51d, 51e, 51f, 51g, 51h, 51i and 51j and an inner or core group 53 of 4 strand groups a, b, c and d. The sense of the twisting of each one of the strand groups is indicated by an arrow, it being noted that each outer group of strands 51 is twisted oppositely from its adjacent strand group, group 51a being opposite to 51b—51j being opposite to 51a.

The groups a—d of core groups 53 are also twisted oppositely in the same manner as those of the outer group. The groups of the core 53 are elliptical in cross section so that as a result the wear points due to induced magnetic fields occur only at the six points 55. This reduces chafing.

The function of the perforated resilient core assembly in the alternate polarity type cable of this disclosure is similar to that given in applicant's U.S. Patent No. 3,143,593 for a pulsating flow core of a diametrically opposite type cable, whereby the "kicking" or pulsating action of the conductors due to their reactive forces alternately moving towards and away from the loosely fitting elastic tubing cause a lateral displacement of water from the central core in a flushing "eddy current" manner. The correct proportions of each of the negative and positive metering ports result in the desired optimum balance of 55% of total flow passing through the passageways among the positive ropes and 45% along the passageways among the negative outer ropes. As the hose ages, it will expand and the flow balance will change to a 50—50%.

The cable described in this invention and noted as Cable C has been competitively tested along with the type of cables described in U.S. Patent No. 2,594,777 and U.S. Patent No. 2,691,691 called Cable A, and U.S. Patent No. 2,702,311 called Cable B. The results have been summarized and are tabulated below:

Cable Type	*Electrical Cycles Before Failure*	*Mechanical Cycles Before Failure*
A_1	3,280,000	982,000
A_2	2,900,000	870,000
B_1	2,260,000	680,000
B_2	3,350,000	1,005,000
C_1	12,500,000	3,750,000
C_2	10,500,000	3,150,000

The results show conclusively that the cable of Type C of this disclosure has three times the potential life of either of the other

two types of cables that are now commercially available and previously identified as A and B cables. It should be noted Cables C_1 and C_2 were still functioning when they were removed from the test stand. Upon their examination, it was estimated that the expected life span approaches 15,000,000 electrical cycles. The test simulated actual automative production line conditions by using a special machine that can repetitively duplicate the many mechanical motions performed by the welding gun operator while using a portable welding tool to spot weld auto body components along a moving assembly line. The electrical testing was concurrently performed on the cables while they were subjected to mechanical flexing motions. A constant load of 18,000 amps was maintained at 200 times per minute consisting of 4 weld cycles or 22.2 duty cycle. A sufficient water pressure differential was chosen at the beginning of the test in order to permit 2 GPM of coolant flow and thereafter maintained at this level. Inlet flow temperature was maintained at 75° and the conductivity and water flows allowed to vary decreasingly in accordance with the cable's rate of deterioration until total failure resulted.

Although the cable of the present invention has identical construction both at the gun end and transformer end, these respective ends have different types of failures and, in practice, there is no system for confining the cable's usage to a transformer end or a gun end. It must be interchangeable for both ends, and must be usable by unskilled personnel.

It will be apparent from the foregoing description that the nylon sleeve and the manifold connector grooves are not important at the transformer end, but become vitally necessary at the gun end for (1) preventing mechanical wear and (2) achieving water balance in the cable.

Therefore, the ends of the cable are built symmetrically although some functions of the components are not important at one or the other end of the cable.

WHAT I CLAIM IS:—

1. A connector assembly for an electrical welding installation comprising a kickless electric cable having helically disposed ropes of conductor strands, and including means for supporting the ropes, said means being located internally of the conductor ropes of the cable and in a region towards an end of the cable and presenting helical grooves each supporting a rope, the helical angle of the grooves being approximately equal to the helical angle of the lay of the ropes, said grooves providing sliding surfaces for the supported ropes, whereby to hold the ropes apart and facilitate their relative longitudinal movement without chafing during bending and twisting of the cable in use, conductive connector means being provided for securing the assembly to said installation.

2. An assembly according to claim 1, wherein perforated tubular means is located centrally of the cable to provide a passage for coolant fluid introduced at one end of the cable and expelled at the other end, and said support means has a central bore accommodating a continuation of a component of such tubular means.

3. An assembly according to claim 2 wherein the tubular means comprises a coiled spring-like element of open pitch located within a perforated tube, and the coiled element is accommodated in the bore of said support means.

4. An assembly according to any of claims 1 to 3 wherein said support means has grooves with sliding surfaces for a plurality of ropes of one polarity which are located in a common inner insulating sleeve in a clover-leaf or like pattern, and alternate in circumferential spacing with a plurality of ropes of the other polarity located in a common outer insulating sleeve.

5. An assembly according to any of claims 1 to 4 wherein a second support means is located in the vicinity of said end of the cable and externally of the conductor ropes of the cable and presents an inner sliding surface to facilitate movement of ropes during bending and twisting of the cable in use.

6. An assembly according to claim 5 wherein said second support means comprises a semi-rigid sleeve of insulating material located within a common outer insulating sleeve of the cable for contact with ropes of only one polarity.

7. An assembly according to any of claims 1 to 6 wherein a conductive connector means at said end of the cable comprises a pocket portion receiving a plurality of the conductor ropes of one polarity in a helical shape approximating in helical angle to the lay of the ropes.

8. An assembly according to any of claims 1 to 7 wherein a first conductive connector means at said one end of the cable comprises a pocket portion receiving a plurality of the conductor ropes of one polarity and defining a central space, and a second conductive connector means at such end of the cable comprises a pocket portion receiving a plurality of the conductor ropes of the other polarity and presenting a hump accommodated in said central space.

9. An assembly according to claim 8 wherein said second connector means has a substantially axial passage for coolant fluid through the otherwise rope-filled pocket portion and opening through a port into a space between the connector means.

10. An assembly according to claim 9 wherein said first connector means has an open ended circumferentially extending manifold channel connecting with helical channelling to distribute coolant flow over the respective ropes of said one polarity.

11. An assembly according to any of claims 7 to 10 wherein each connector means is electrically but removably connected to a respective terminal element.

12. An assembly according to claim 11 wherein each said connector means has an internal surface doubly bevelled for close overlap fit with a corresponding doubly bevelled form of an outer surface of a tang of the terminal element.

13. An assembly according to claim 11 or 12 wherein two terminal elements one of each polarity are secured in abutting relation with interposition of a sheet of insulation, and at least one terminal element has a passage for coolant fluid passing through a space defined between the terminal elements and a continuation of such space between the two respective connector means.

14. An assembly according to claim 4 or any other claim as appendant thereto, wherein the common inner and outer insulating sleeves accommodate predetermined proportions of coolant fluid flow.

15. An assembly according to claim 9 or any other claim as appendant thereto wherein said port is formed as a flow metering port.

16. An assembly according to any of claims 1 to 15 wherein each rope of the cable comprises 14 groups of strands consisting of 4 groups of non-circular section forming a core section and 10 groups forming a peripheral section surrounding said core section, adjacent strand groups of both said peripheral and core sections are alternately oppositely twisted, and the arrangement is such as to provide only six electrical wear points in the cross-section of each rope.

17. An assembly according to claim 16 wherein said core strand groups are substantially elliptical in cross-section.

18. An assembly according to claim 16 or 17 wherein said core section is structurally stable to support the peripheral groups in the required relative positions.

19. A connector assembly for an electric welding installation, substantially as hereinbefore described with reference to and as illustrated in the accompanying drawings.

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Sheet 1

FIG.1

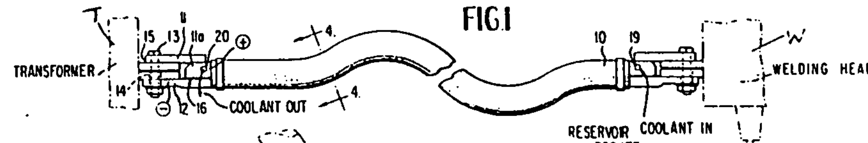


FIG.3

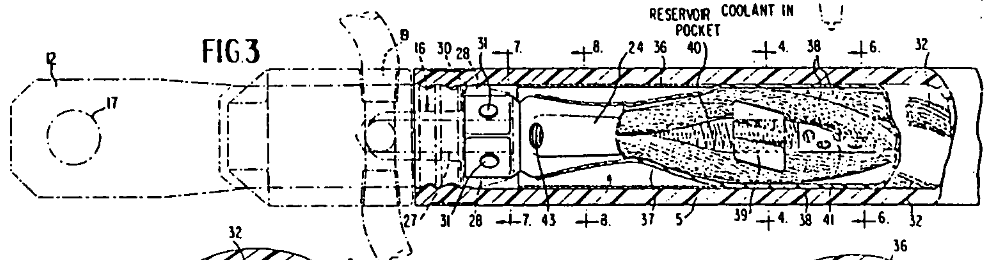


FIG.6

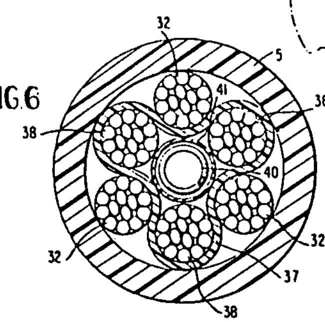


FIG.7

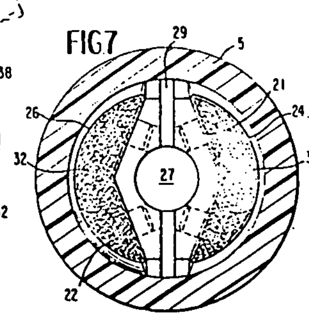
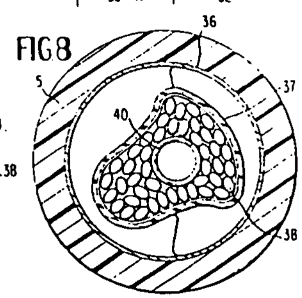


FIG.8



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Sheet 2

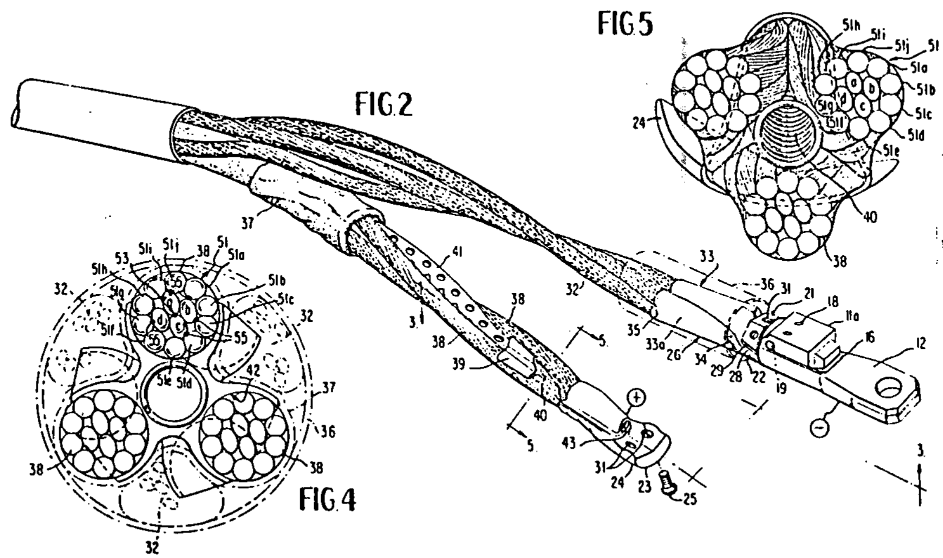

FIG.5

FIG.2

FIG.4